ON AN AUTOMATIC WILSON CLOUD CHAMBER IN A MAGNETIC FIELD AND SOME ASSOCIATED TECHNIQUES*

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Plate XVII

ABSTRACT. An one ton electromagnet for use in cosmic ray research with a shallow cloud chamber, has been installed in the Institute of Nuclear Physics. For convenience in photography, one of the pole pieces has been bored. The field strength attainable with a current of 7 amperes is about 3630 gauss over the effective region in the pole gap. A shallow cloud chamber, 2.5 cm deep and 15 cm in internal diameter, has been used. A complete description of the automatic sequence control mechanisms has been given. In automatic test runs, tbe performance of the apparatus has proved quite satisfactory.

INTRODUCTION

The importance of a properly calibrated magnetic field for some specific cosmic ray experiments cannot be over-estimated. For instance, in experiments on the determination of mass of cosmic ray particles from momentum loss in a metal plate of suitable thickness placed inside the cloud chamber, in finding out the energy spectrum of charged particles from measurement of curvatures, in distinguishing positive particles from negative ones and also, to fix the ratio of their numbers, a suitable magnetic field is a prerequisite. Most of the modern cloud chambers are fitted with very powerful magnetic field producing devices. The electromagnets used by Kunze (1933), Anderson (1933), Blackett (1936), Hughes and Jones (1940) and others are very big and massive; they are capable of producing high fields at a comparatively high power consumption. For the quantitative studies of cosmic ray particles in the high energy region of the energy spectrum, high fields are absolutely necessary. For the study of particles in the low energy region, however, smaller fields can be conveniently produced with not too massive electromagnets, at a reasonable power consumption. Besides reducing the cost, the use of lesser amount of iron and copper for the electromagnet has the additional advantage of reducing undesirable scattering effect.

With the above ends in view, and especially for experiments with a shallow cloud chamber, we have installed an electro-magnet with other accessory mechanisms. A shallow cloud chamber, 2.5 cm deep and 15 cm in internal diameter, has been used. The very light diaphragm of the chamber has necessitated the development of an automatic electro-mechanical

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device to keep the compressing pressure stabilized within a narrow range on either side of the optimum working value. The illumination for photographing tracks is provided with an arc discharge flash lamp (F.T. 126, Int. G.E.C). A simple and reliable triggering circuit has been developed for firing the flash lamp. An objectionable feature of employing flash lamps in cloud chamber photography has been noticed and a simple electronic device has been made to counteract this.

The details of the different parts of the entire unit are given under their respective headings.

(a) *The Electromagnet.*—The electromagnet is horse-shoe shaped. The core proper weighs nearly 18 mds. (1440 lbs), each magnetising coil 2½ mds. (200 lbs) and the pole-piecess 1½ mds (120 lbs) each. The magnetising coil consists of 20 layers (each 108 turns) of 11 S.W.G. (about .345 cm) copper wire. The wire is silk covered, having a surface layer of lacquer to insure sufficient insulation. The total resistance of the magnetising coils is 3.5 Ohms. The dimensions of the magnet and coils are given in figure 1. The magnet has been seated on three massive stone chip pillars 94 cm high. To increase structural strength, the pillars have been interconnected by means of a reinforced transverse block 17½ cm high. Liberal spacing has been kept between front pillars seating the pole-pieces so that, if occassion demands, about 70 cm of lead absorbers can be used underneath the cloud chamber. The magnet current is supplied from the laboratory 220 D.C. mains, using variable resistances to alter the magnetising current. Considering the statistical errors involved in the types of experiments that can be done with the apparatus, we have not felt it necessary to introduce any current-stabilizing device at present. With the magnet running for 24 hours at a 6 amperes rating, the increase in the temperature of the core is just a little over ½°C. This has been measured by means of thermometer dipped in mercury in a narrow hole drilled in the pole piece carrying the cloud chamber. It is expected that with an air blast arrangement sufficient cooling can be produced to push down the rise in temperature to ¼°C, which will not greatly disturb the performance of the chamber.

The pole-piece facing the cloud chamber has a cylindrical hole of 4¼ inch diameter and 9 inch axial length, so that photographs can be taken directly. The hole has, of course, introduced a certain degree of non-uniformity and also a considerable amount of reduction in the effective field strength. For this reason, the calibration of the magnetic field has been done rather elaborately. A simple and specially designed search coil device has been used for the three dimensional mapping of the magnetic field. For this purpose, the entire pole gap has been divided into 10 vertical planes parallel to the pole faces, with a spacing of 1 cm between successive planes. Each of these planes, again, has been divided by 12 vertical and 10 horizontal lines and field strengths at the points of intersections measured. In this way the entire field space has been investigated. The results of the field

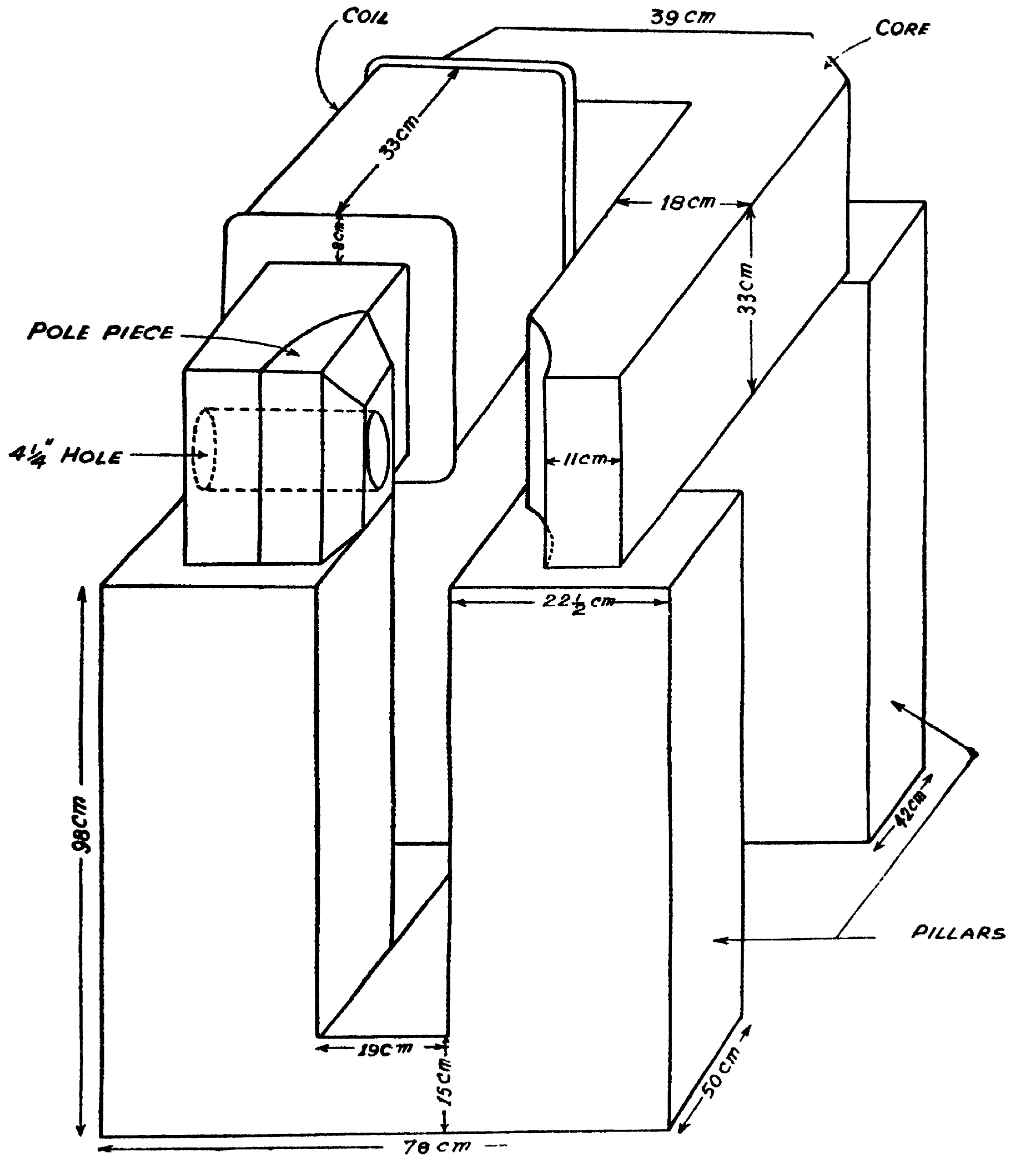

FIG. 1

Perspective view of the magnet and supporting pillars (for clarity, right hand coil and pole-piece not shown)

investigation have been graphically represented (figure 2). It has been found that for a given plane parallel to the pole faces, the deviation of the field strength near a peripheral region of about 2 cm is about 15% of the more or less uniform value in the central region of that plane. It is seen from the plot that upto a distance of about 3 cm from the pole-piece supporting the cloud chamber, the fall in the field strength in the effective region is almost linear ; the field strength for the remaining region upto the drilled pole piece is sensibly constant. With the cloud chamber we have designed, the glass ring occupies the region of constant field strength. Thus, for all practical

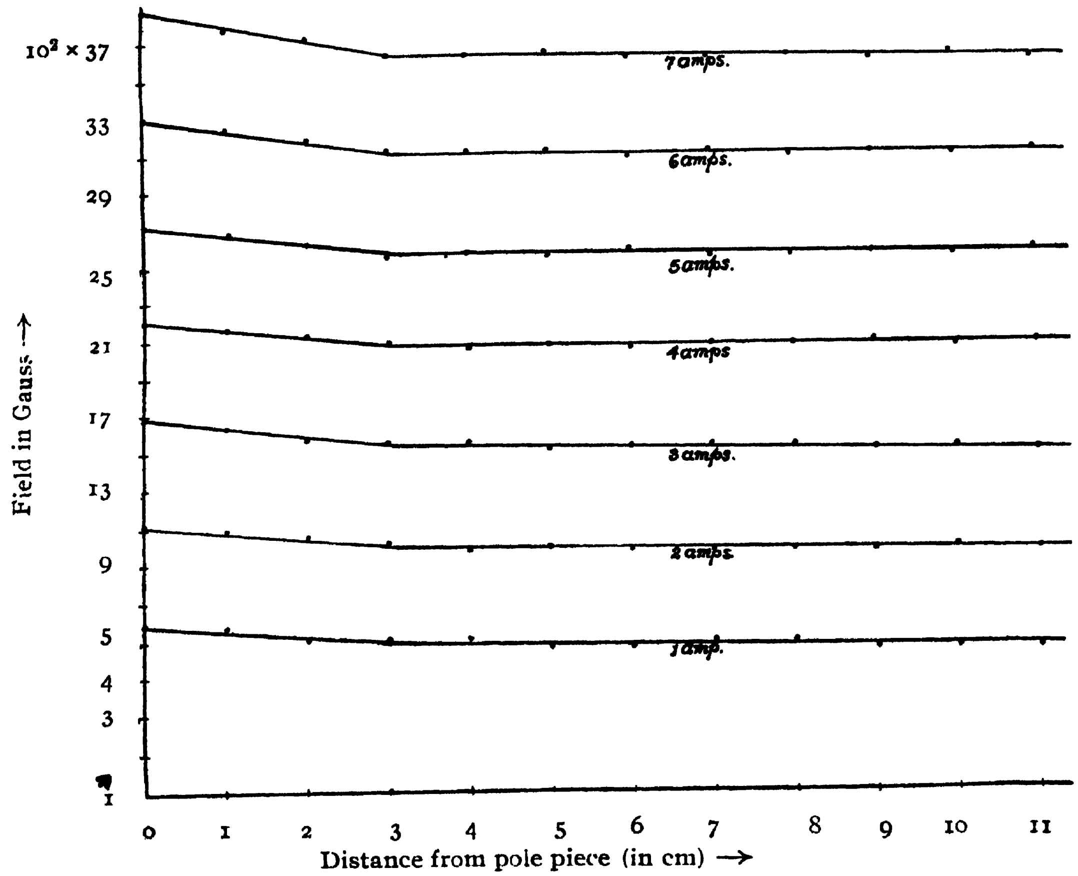

FIG. 2

Variation of field in the effective reginn

purposes, the same calibration curve will serve for chambers of different depths.

(*b*) *The magnet circuit breaking device.*—It is well known that when a coil of large self inductance carrying a sufficiently heavy current is opened, a large back E.M.F. is developed at the points of opening and thus, the breaking switch is gradually damaged due to sparking. To obviate this, a very simple device has been used (figure 5). Two 150 watts, 110 volts lamps have been arranged in parallel with the magnet coils. Normally, when the magnet is on, the lamps are off. Just prior to breaking the magnet current, the lamps are switched on, so that they glow due to the current from the mains. Now, when the mains are cut off, the magnet coils and the lamp filaments fall in series, so that the surge current due to the back E M.F. finds a closed path of considerable resistance. Consequently, the damage due to the heavy sparking in the open circuit is avoided.

The cloud chamber.—A sectional diagram of the cloud chamber is given in figure 8. The bottom of the chamber has been specially designed to fit closely the protruding disc on the pole-piece on which it is secured by means of two radial screws.

The diaphragm of the cloud chamber has been made of two 5 inch circular aluminium discs 1/16 inch thick, with a larger diameter rubber-cloth sand-wiched between them by means of a large number of peripheral rivets. Thus constructed, the diaphragm is very light and hence, fast in action. The requisite expansion ratio is controlled by means of three lateral conical plugs carrying wedge-pieces at their ends. The conical plugs have been very carefully ground to reduce the air leakage from the back compartment as far as possible. The forward position of the diaphragm is limited by the brass ring on which the glass ring of the cloud chamber has been mounted; the backward position (that is, when the actual expansion of the chamber has taken place) is determined by the position of a baffle plate, attached to the bottom of the cloud chamber by means of three short springs. The position of the baffle plate and hence, the expansion ratio of the chamber, is controlled by moving the wedge-pieces either inwards or outward. This will be clear from the sectional diagram of the chamber. There is a pressure gauge to record the initial and final pressures in the chamber.

The supply of compressing air.—Although the compressing air is supplied by means of an automatic air compressor, the reducer valve itself is not sufficient to give a pressure-stabilized supply of air. As the diaphragm is rather delicate, any excess compressing pressure has a tendency to buckle it, so that, the optimum conditions for recording tracks of particles passing through the chamber are disturbed. For this reason, a subsidiary electro-mechanical device has been developed by the author (Das, 1950), which, in conjunction with a stabilizer tank, maintains the pressure of the compressing air stabilized within a narrow range. A detailed description of the construction and working of this pressure stabilizing device has been published earlier.

The expansion valve—The design and performance of the expansion valve is a very important consideration in any cloud chamber work. We have used a valve of the Fussell type, being the simplest and most convenient. Use of this type of valve has a few advantages over the older types.

Unlike in older procedures (Das Gupta and Ghosh, 1946), in this case the valve is directly connected to the primary control rod passing through the axis of the soft iron core of the solenoid magnet and thus, it is absolutely free from any uncertainty as regards its final action, viz., closing the expansion hole. With the older type of valve one cannot be too sure of its final action; one has to pay almost a periodical attention to it. Besides eliminating a potent source of trouble, the adoption of the Fussell type of valve has greatly simplified the accessory mechanisms controlling the automatic setting of the valve. A sectional diagram of the valve is given in figure. 3.

The illuminating system—As the effectively accessible region in the immediate vicinity of the sensitive volume of the cloud chamber to be photographed is rather limited, the normal procedure of using 110 volts (and usually 150 watts) lamps at a momentary over-loading of 220 volts

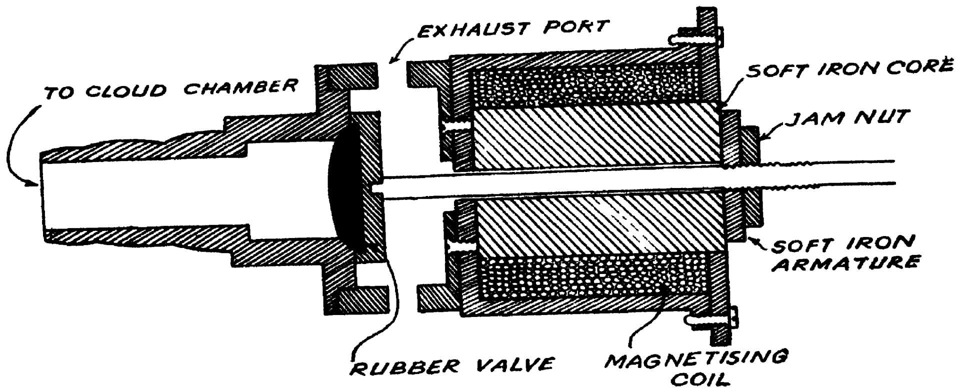

FIG. 3
Sectional diagram of the valve system

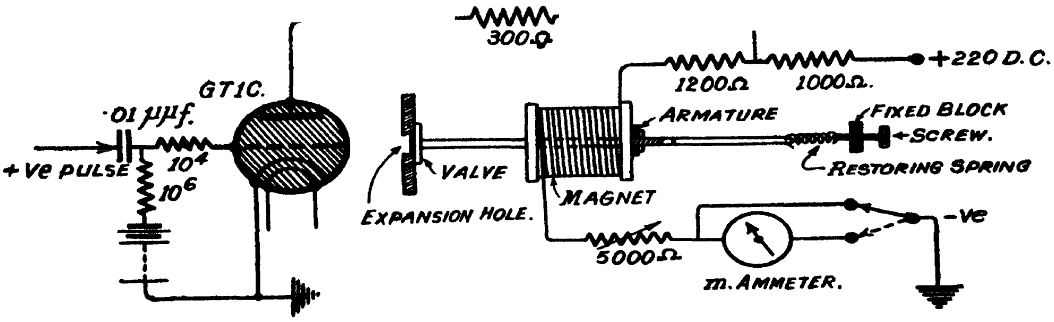

FIG. 4
Thyratron, shunting the valve-magnet (valve-resetting mechanism not shown)

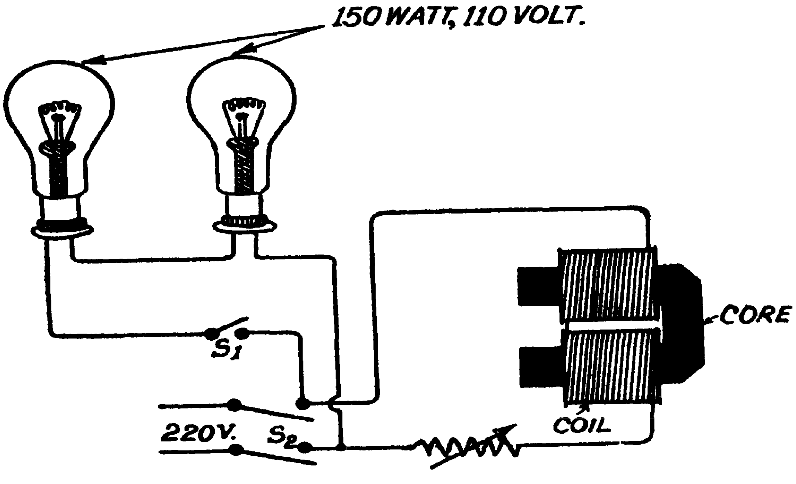

FIG. 5
Electromagnet circuit breaker

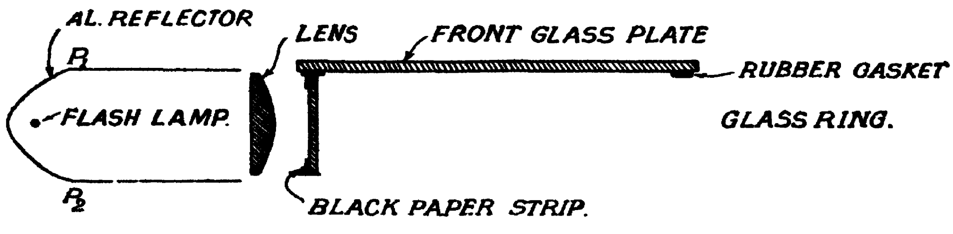

FIG. 6
Illuminating system

would not do. The geometrical configuration in the present case would compel us to use one such bulb above and the other below the chamber; consequently, the expansion initiating G.M. counters can not be used for distances less than 16 inches. The focusing of the beam through the effective volume of the chamber also bocomes very imperfect with this arrangement. Besides, the presence of the material of the bulbs in the path of the incoming cosmic rays is not desirable from more than one stand-points. We have solved this difficulty by using modern arc discharge lamps.

A single tube (capillary length 6 inches) has been used from the front edge of the chamber. The capillary of the flash tube has been backed by a 6 inch high parabolic cylindrical reflector, made of 1/16 inch aluminium sheet (figure 6). The part $P_1 P_2$ of the reflector is shaped accurately parabolic, the focal axis coinciding with the capillary. The focus of the parabola is also at the focus of the plano-cylindrical condensing lens (2 inch focal length, 6 inch long, 1 inch aperture), so that we get a highly intense and almost parallel beam of light. To increase the reflecting power, an 1 mil. thick aluminium foil has been fixed, without any kink, on the reflector.

To fire the flash tube, a simple and efficient triggering device has been developed in our laboratory. A detailed description of the design and operation of the triggering device has been published earlier (Das, 1950). One objectionable feature of these flash tubes is that they sometimes flash over erratically, that is, give light flashes without any correlation with any recordable event, which, in the present case, is the passage of a charged particle through the cloud chamber. It seems that flash tubes controlled by means of external triggering electrodes invariably suffer from this defect (Bourne, 1948). To counteract the effect of this erratic behaviour on cloud chamber photography, a simple electronic device has been developed by the author (Das, 1950).

The automatic sequence control mechanism—The control sequences can be described under the following headings:

(1) Firing the thyratron shunting the electro-magnet of the expansion valve, by a voltage pulse from a desired event.

(2) Release of the armature carrying the valve (expansion of the chamber).

(3) Triggering the flash tube within .01 second of the expansion.

(4) Setting the driving motor in motion.

(5) Resetting the valve.

(6) Winding up the exposed portion of the film.

(7) Breaking the motor circuit at the end of the cycle.

The positive pulse due to the occurrence of a recordable event fires the thyratron which is in parallel with the magnetising coil of the valve magnet (figure 7). Now, during the conducting stage, tho total resistance of the thyratron circuit (that is, internal resistance of the thyratron plus the external

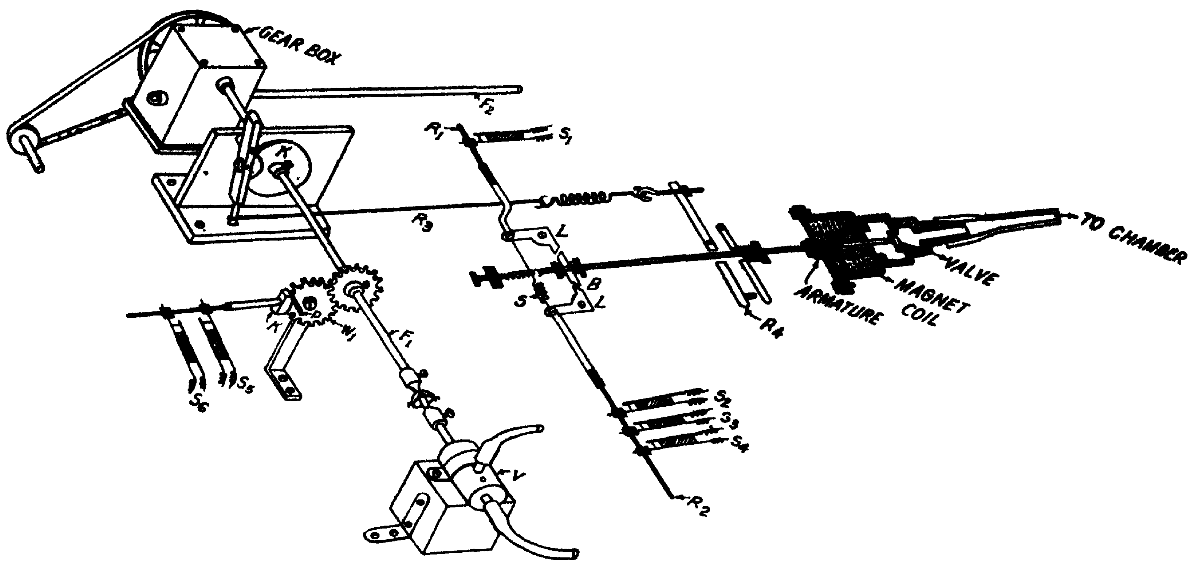

FIG. 7

Automatic sequence control mechanism (For clarity, some parts have been drawn sectionally)

current limiting resistance R) is much smaller than the resistance of the magnetising coil, so much so, that the thyratron acts as a shunt to the magnet circuit. As the magnetising current is kept just at the optimum level (in this case 30 milli-amps) the armature flies off ; consequently, expansion of the chamber takes place (figure 4).

After the release of the valve, the bevelled aluminium block (figure 7) B occupies a position, displaced considerably in the forward direction ; consequently, the L-pieces are moved laterally. This lateral movement is communicated through the long levers R_1 and R_2 to the various switches S_1, S_2, S_3 and S_4. Each of the electric switches is made of a thin and a thick phosphor-bronze strip with lengths so adjusted as to give sufficient restoring force. The actual contact points are of platinum so that corrosion due sparking is greatly reduced. The switch S_2 breaks the plate of the thyratron, thus extinguishing it. The swith S_3 removes the pre-expansion ion-sweeping field just after the expansion of the chamber.

The switch S_1 sets the driving motor in motion. Now, the position of the cam K has been so adjusted initially, that just after the motor starts it begins to pull the lever rod R_3. This motion is transmitted through the lever arm R_4 to the magnet armature which is gradually pushed toward the magnet core until it is kept attracted to it. Under the joint restoring action of the phosphor-bronge strips and the steel spring S, the switches S_1, S_2, S_3, and S_4 are restored to their initial positions within 10 seconds of the starting of the motor. Now, the pin P fixed to the pinion wheel W is moved past the contact knob K_1 so that the motor circuit is now closed through the switch S_6, until it is again broken by the separation of the

Secondary electron tracks, produced by γ-ray contact points at the end of the cycle by the pin P. The switch S_5 is such that it finally closes the thyratron plate circuit. As the complete cycle of automatic sequences lasts for nearly $1\frac{1}{2}$ minutes, it is clear that without the switch S_5, which closes the thyratron plate circuit at the end of the cycle, there is always a risk of the chamber being tripped within a cycle; that is, before it has been reset completely.

The cone of the cup-cone air inlet valve V is rigidly pinned to the shaft F_1. During the time the motor is in motion, the cone completes the rotation and establishes communication of the back compartment of the cloud chamber with the air pressure stabilizer. The second shaft F_2 in conjuction with two arms joined by means of universal gimbals, winds up the exposed portion of the film, so that a fresh portion of the film comes up for recording the next event. In this way, the entire sequence of automatic control is completed.

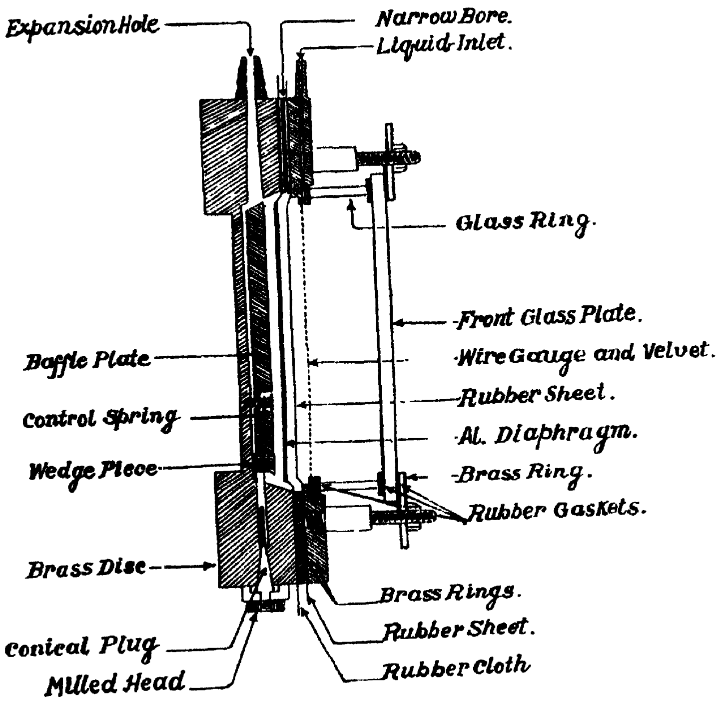

FIG. 8

Transverse view of the cloud chamber

The Photographic Arrangement:—At present we are using a single lens arrangement for photography. This is justified in view of the fact that the chamber is a shallow one. However, there is ample provision for diverting to a stereo arragement, if need arises. The lens used is Sonnar $1:2 f=4$ cm. The film plane is at an effective distance of 16 inches from the front glass plate and the pictures obtained have a diameter of 1.7 cm, that is, the reduction in size is nearly in the ratio of 8.3 : 1.

THE PERFORMANCE OF THE APPARATUS

A few automatic test runs of the complete apparatus were made by means of three Geiger Muller counters in coincidence. The cloud chamber was filled with a mixture of air and oxygen up to a total pressure of 84 cm of mercury. The liquid mixture used was 40% water and 60% absolute alcohol. A Ra-source was placed at a distance of 8 ft. and a collimated beam of gamma rays allowed to enter the cloud chamber. This step was taken, because, when the chamber expands due to accidental coincidence of G. M. counter pulses, there will be, in general, no track formation inside the cloud chamber and, this is specially true for a shallow could chamber. An ionising agent, such as a weak gamma source, properly shielded from the counters, would always send a few γ-rays into the chamber, producing secondary electrons. Thus, the condition of the cloud chamber as regards formation of tracks can be checked at any stage of the operation of the chamber. In a test picture supplied, plate XVII, the secondary electron tracks are quite clearly seen. The picture also shows a long track presumably due to a charged cosmic ray particle. We hope to put the apparatus to the study of some suitable cosmic ray problem involving the use of a magnetic field of the order of 3, 500 gauss.

ACKNOWLEDGMENTS

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